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Comparative Microbiological Evaluation of Raw Chicken from Markets and Chilled Outlets of Mauritius

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ABSTRACT

The present study was carried out to compare the microbiological status of raw chicken thighs purchased from two main markets and chilled retail outlets of Mauritius. In order to determine the microbiological acceptability of the lots sold in the different outlets, random representative samples were purchased and microbiologically analysed for Total Viable Counts (TVC), *Staphylococcus aureus*, *Escherichia coli*, *Campylobacter* spp. and *Salmonella* spp. Two independent trials were conducted and the results were interpreted against published microbiological criteria for raw poultry. Microbiological results indicated that the lots of raw chicken at the two markets and one chilled outlet were deemed unacceptable for sale when compared with the microbiological criteria for acceptable lots. In addition, the results showed that the population of TVC (5.8 log cfu/g) and presumptive *Staphylococcus aureus* (4.7 log cfu/g) were significantly higher in chicken purchased from markets than chilled outlets ($P<0.05$). Findings of the present study highlight the need for public health officials to enforce stricter hygiene and food safety measures against market retailers of raw chicken.

Key words: Chicken, Microbiology, Pathogens, Hygiene, Markets

INTRODUCTION

Throughout the world, the production and consumption of chicken has increased. The annual production of chicken meat in Mauritius is 47000 tons (Statistics Mauritius, 2012). The consumption of chicken for the year 2012 was 35.7 Kg per capita (Gaungoo and Jeewon, 2013) compared to 28.06 Kg per capita in the year 2000 (Statistics Mauritius, 2007). Chicken consumption has considerably increased since it represents a major component of the human diet and chicken is an important low cost source of animal protein (Cohen et al., 2007).

Meat is a highly perishable product. If it is not stored, processed, packaged and distributed correctly; it will spoil quickly and become hazardous due to microbial growth (Bolder, 1998). The level of microorganism present in meat products can be reduced only when they are further processed (Jay et al., 2005). If spoilage microorganisms such as *Brochothrix thermosphacta* and *Pseudomonas* spp. are present and grow to a high number, the meat will spoil and will be unfit for consumption (Davies and Board, 1998). Pathogens, such as *Salmonella* spp., *Escherichia coli* and *Staphylococcus aureus* can also grow and cause illness either by multiplication in the human body (food infection), producing toxins (food intoxication) or multiplying and releasing toxins in the body (food toxico-infection). The presence of pathogens in the food supply is considered to be undesirable and they are the major cause of gastrointestinal disease throughout the world (Mead, 1989). In Mauritius, a total of 2653 cases of food poisoning had been recorded from 1990 to 2010 (Hotee, 2011). This number should in fact be multiplied by a factor of 3 to 100 to take into account unreported cases (WHO, 2002).

Unhygienic practices prevailing in poultry slaughterhouses and retail outlets can lead to unsafe and low quality chicken product (Bremner and Johnston, 1996). In Mauritius, poor hygienic practices among poultry meat handlers have often been reported (Gaungoo and Jeewon, 2013). Recently, 253 kg of poultry were seized and destroyed by the Public Health Officers (PHOs) of the Ministry of Health and Quality of Life of Mauritius as birds were illegally slaughtered in a backyard and in unacceptably poor condition of hygiene (L'Express, 2013).

With the recent mushrooming of a large number of poultry retail outlets throughout the island, there is an increasing tendency among Mauritians to purchase fresh chicken from markets and chilled outlets. The objective of this study was to comparatively assess the microbiological safety and quality of raw poultry products sold in markets and chilled outlets of Mauritius.

MATERIALS AND METHODS

Preparation of sample

Raw chicken samples were bought from two main markets and chilled retail outlets located in the capital city (Port-Louis) or commercial town (Rose-Hill) of the island during the period of August to December 2013.

Specifically, 5 random drumsticks were purchased at each selected point of sale and aseptically transported to the laboratory, in a cooler bag with ice packs, for analysis. Table 1 shows the scheme used for sampling of poultry products. Using a flame-sterilized knife, 25g of chicken meat were cut with its skin on, and placed into a sterile stomacher bag to which 225 ml of sterile buffered peptone water was added. It was then blended in a stomacher (Stomacher 400) for two minutes at 230 rpm to produce a homogeneous stomachate sample.

Enumeration of TVC, *S . aureus* and *E . coli*

The stomachate sample was serially diluted in 9 ml of 0.1% sterile buffered peptone water (Accumedia) to achieve a 10-fold dilution. The stomachate and its dilutions were pour plated on plate count agar and the plates were incubated at 30°C for 72±2 hours (ISO 4833:2003) after which the colonies were enumerated using a colony counter.

In addition, the inoculum was also spread plated on Baird Parker agar (ISO 6888-1) and Eosin Methylene Blue agar (Leininger, 2001) for enumeration of presumptive *Staphylococcus aureus* and *E. coli* respectively. Inoculated plates were then incubated at 37°C for 48 ± 2 hours. Chapman Stone Agar and Bromocresol Purple Azide Broth were used to confirm the identity of presumptive *S. aureus*. Cultures suspected to be *E. coli* were confirmed by Gram staining, indole production and catalase tests.

Detection of *Salmonella* and *Campylobacter* spp.

The detection of *Salmonella* species was done according to the ISO standard 6579:2000. Briefly, the sample was enriched in 0.1% buffered peptone water at 35°C for 24 h followed by secondary enrichment in Rappaport Vasiliadis broth at 44°C and subsequent streaking on Xylose Lysine Deoxycholate (XLD) agar. Black or black-centered pink colonies on XLD agar indicated the presence of presumptive *Salmonella*. Suspected colonies were confirmed by streaking on urease and TSI agar slants. Detection of *Campylobacter* spp. was done in accordance with ISO 10272-1 (2006). Briefly, the sample was enriched in double-strength Bolton Broth and incubated at 42°C for 48 h under microaerophilic conditions (5% O_2, 10% CO_2, 85%N_2) generated by using microaerophilic gas packs. Following incubation, a loopful of Bolton Broth was streaked onto modified Charcoal Cefoperazone Deoxycholate (mCCD) agar and incubated at 42°C for 48 h under microaerophilic conditions. Flat grayish colonies characteristic of *Campylobacter* were selected for Gram staining. Gram-negative cells with a curved or S-shaped morphology were confirmed to be *Campylobacter*.

Statistical Analysis

All experiments were conducted in two independent trials. Where appropriate, statistical analyses were conducted using Minitab® Release 17. A single factor analysis of variance (ANOVA) and Tukey's one-way multiple comparisons were conducted to determine differences in the population of the different bacterial species. Significant differences were considered at the 95% confidence level ($P<0.05$).

RESULTS

Microbial load of raw chicken bought at market stalls

According to the Microbiological Criteria set forth by the International Commission on the Microbiological Specification for Foods (ICMSF, 1986), for a lot of raw chicken to be considered acceptable, not more than one out of five samples of the lot can test positive for *Salmonella* (Table 1). However, the lot from main market 1 (M1) contained more than one *Salmonella*-positive samples (4 out of 5), making the lot unacceptable. The microbiological criteria for TVC are such that only 3 out of 5 samples can have a microbial load of 5 X 10^5 to 10^7 cfu/g as indicated in Table 1. However, the TVC of more than three samples were at least one order of magnitude higher than 10^5 cfu/g.

Microbiological criteria of *Staphylococcus aureus* and *Escherichia coli* were additionally not met. Out of five samples analysed for *Staphylococcus aureus*, more than 3 had a microbiological load greater than 10^3 cfu/g. For *E. coli*, all the five samples analysed had a higher value than the maximum acceptable limit of 2 X 10^3 cfu/g on both occasions. The complete sets of microbiological data obtained for individual samples are shown in Table 2. Taken together, results indicated that the lots were unacceptable on both instances.

Table 1. Sampling plan and microbiological criteria for raw poultry

Microorganism	Attribute plan	n	c	m	M
Total Viable Count (cfu/g)	3	5	3	5 x 10^5	10^7
S. aureus (cfu/g)	3	5	3	10^3	10^4
E. coli (cfu/g)	3	5	2	10^2	2 x 10^3
Campylobacter (/10 g)	2	5	1	0	-
Salmonella (/25 g)	2	5	1	0	-

Lots sampled from main market 2 (M2) should also be rejected. During both sampling rounds, *Salmonella* was detected in more than one sample. Criteria regarding TVC, *S. aureus*, *E. coli* and *Campylobacter* were also not fulfilled; for the first visit, more than 3 samples had a TVC load of ca. 10^6 cfu/g while the population of *S. aureus* was approximately 10^4 cfu/g in more than three samples.

In addition, two samples had a charge of *E. coli* in excess of 10^2 cfu/g, hence constituting additional grounds for rejection of the lot on both times. The complete sets of microbiological data obtained for individual samples are shown in Table 2.

Table 2. Microbial load of raw chicken purchased from market M1 of Port-Louis (capital city) during August - December 2013

Parameters	1st Visit					2nd Visit				
	Sample 1	**Sample 2**	**Sample 3**	**Sample 4**	**Sample 5**	**Sample 1**	**Sample 2**	**Sample 3**	**Sample 4**	**Sample 5**
TVC (cfu/g)	7.8×10^5	3.0×10^6	3.3×10^6	5.4×10^5	4.8×10^5	3.5×10^6	3.7×10^6	3.3×10^6	2.6×10^6	2.9×10^6
S. aureus (cfu/g)	4.8×10^4	2.8×10^4	5.5×10^4	4.0×10^4	6.2×10^4	7.8×10^4	7.0×10^4	5.7×10^4	7.2×10^4	6.1×10^4
E. coli (cfu/g)	6.8×10^4	8.1×10^4	3.0×10^4	6.6×10^4	5.6×10^4	3.5×10^4	3.9×10^4	3.4×10^4	2.8×10^4	4.3×10^4
Campylobacter/25g	-	+	+	-	+	-	+	+	+	+
Salmonella /25g	-	+	+	+	-	+	-	+	+	+

Table 3. Microbial load of raw chicken purchased from market M2 of Rose-Hill (commercial town) during August - December 2013

Parameters	1st Visit					2nd Visit				
	Sample 1	**Sample 2**	**Sample 3**	**Sample 4**	**Sample 5**	**Sample 1**	**Sample 2**	**Sample 3**	**Sample 4**	**Sample 5**
TVC (cfu/g)	1.1×10^6	1.2×10^6	1.3×10^6	1.4×10^6	4.2×10^5	5.1×10^5	3.4×10^4	6.5×10^3	1.7×10^4	2.4×10^4
S. aureus (cfu/g)	4.7×10^4	7.2×10^4	7.6×10^4	7.5×10^4	6.7×10^4	5.9×10^4	5.2×10^5	< 100	< 100	5.3×10^5
E. coli (cfu/g)	9.1×10^3	2.0×10^3	3.0×10^2	5.5×10^2	4.5×10^2	7.7×10^5	4.9×10^5	4.6×10^5	4.2×10^5	4.3×10^5
Campylobacter/25g	-	+	-	+	-	+	-	+	-	+
Salmonella /25g	-	-	+	+	+	+	+	-	-	-

Table 4. Microbial load of raw chicken purchased from chilled outlet CO1 of Port-Louis (capital city) during August - December 2013

Parameters	1st Visit					2nd Visit				
	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
TVC (cfu/g)	1.2×10^7	1.2×10^6	1.4×10^6	1.1×10^6	1.1×10^5	2.5×10^5	3.6×10^5	1.3×10^5	1.4×10^5	3.9×10^5
S. aureus (cfu/g)	1.9×10^4	2.1×10^4	1.6×10^4	2.9×10^4	2.7×10^4	1.9×10^4	<100	<100	2.1×10^4	2.5×10^4
E. coli (cfu/g)	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
Campylobacter/25g	-	-	-	-	-	-	-	-	-	-
Salmonella /25g	-	-	-	-	-	+	-	-	-	-

Table 5. Microbial load of raw chicken purchased from chilled outlet CO2 of Rose-Hill (commercial town) during August - December 2013

Parameters	1st Visit					2nd Visit				
	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
TVC (cfu/g)	2.8×10^4	2.9×10^5	<100	2.7×10^6	3.7×10^5	< 100	< 100	< 100	< 100	< 100
S. aureus (cfu/g)	< 100	< 100	< 100	< 100	< 100	< 100	< 100	< 100	< 100	< 100
E. coli (cfu/g)	< 100	< 100	< 100	< 100	< 100	< 100	< 100	< 100	< 100	< 100
Campylobacter/25g	-	-	-	-	-	-	-	-	-	-
Salmonella /25g	-	-	-	-	-	-	-	-	-	-

Microbial load of raw chicken bought at chilled outlets

Samples purchased from the first main chilled outlet (CO 1) had a high level of TVC and *Staphylococcus aureus* of the order of 10^6 cfu/g and 10^4 cfu/g respectively, rendering the lots unacceptable for sale. During the second sampling round, the level of TVC in the raw chicken was in compliance with the microbiological standard with none of the samples exceeding 500,000 cfu/g. Furthermore, *E. coli*, *Salmonella* and *Campylobacter* were not detected in any of the five samples. *S. aureus* was present in three of the five samples thus making the lot marginally acceptable (Table 4). Samples purchased from the second main chilled outlet (CO 2) were of higher hygienic quality. The TVC determined after the first round of sampling and analysis was of the order of 10^5 cfu/g. However, *S. aureus* and *E. coli* were both undetectable by the plating methodology.

In addition, *Campylobacter* and *Salmonella* were undetectable after enrichment (Table 5). The microbiological acceptability of the poultry lots at the four retail points are summarized in Table 6 for both visits.

Comparison of the microbial load of fresh chicken sourced from the four points of sale indicated that there was no statistically significant difference ($P > 0.05$) with respect to total viable counts and *Escherichia coli* among the four retail outlets (Table 7). In addition, there was no statistically significant difference ($P > 0.05$) in the population density of *S. aureus* between the two major markets, M1 and M2 (Table 7). However, the microbial load of *S. aureus* of chicken purchased from the first chilled outlet (CO1) was significantly higher than the second major chilled outlet (CO 2) ($P<0.05$).

Table 6. Summary of decisions with respect to microbiological acceptability of the lots analysed from August to December 2013 from markets and chilled outlets of Port-Louis and Rose-Hill

Items		1st Visit	2nd Visit
Main Market (M)	M1	Rejected	Rejected
	M2	Rejected	Rejected
Major Chilled Outlet (CO)	CO 1	Rejected	Accepted
	CO 2	Accepted	Accepted

Table 7. Comparative microbial assessment of raw chicken from the different retail outlets of Port-Louis and Rose-Hill from August to December 2013

Parameters	Main Markets		Major Chilled Outlets	
	M1	M2	CO 1	CO 2
TVC	6.4 ± 0.1^{A}	5.7 ± 1.0^{A}	5.3 ± 0.5^{A}	3.9 ± 1.4^{A}
S. aureus	4.8 ± 0.0^{A}	4.6 ± 0.3^{A}	4.2 ± 0.6^{AB}	3.0 ± 0.0^{B}
E. coli	5.1 ± 0.4^{A}	4.4 ± 1.9^{A}	$< 2.0\pm 0.0^{B}$	$< 2.0\pm 0.0^{B}$

Values represent mean obtained from two replicates; Values of the same row having the same superscript letters are not significantly different ($P>0.05$)

DISCUSSION

Total viable counts of raw chicken

Total viable counts (TVC) are a widely accepted measure of the general degree of microbial contamination and hygienic conditions of processing plants (Cohen et al., 2007). Since the TVC counts observed for fresh chicken samples purchased from the two main markets were higher than the level allowed in Table 1, the lot of chicken purchased from the two main markets were deemed of unacceptable quality at both times. In addition, the TVC of chicken purchased from one of the major chilled outlet (CO 1) was unacceptably high after the first visit. Overall, the mean TVC of raw chicken collected from markets and chilled outlets fell in the range of 5.7-6.4 and 3.9-5.3 log cfu/g respectively.

The results of this study are comparable with those of several authors who also reported a variable load of total viable counts in poultry meat. Cohen et al. (2007) showed that the population of total aerobic mesophilic aerobes fell in the range of 5.6-6.6 and 4.5-5.9 log cfu/g for chicken purchased from markets and supermarkets respectively. Kozacinski et al. (2006) reported that the mean population of aerobic mesophilic bacteria varied from 3.7 log cfu/g (breasts with skin), 4.7 log cfu/g (fillets) to 5.4 log cfu/g (retail cut chicken meat). Mean population density of 4.4 log cfu/g of chicken breast meat was reported by Saleh et al. (1997). Alvarez-Astorga et al. (2002) observed TVC as high as ca. 5.8 log cfu/g in chicken drumsticks and chicken wings and slightly lower counts (5.2 log cfu/g) in ground meat. Rashad (1990) observed a wide spread in the TVC (4.3 to 6.4 log cfu/g) of ground chicken meat. Similarly, a wide dispersion in the total aerobic mesophilic bacteria (4.0 – 8.0 log cfu/g) was reported by El-Khateib (1997). Amara et al. (1994) reported TVC of chicken meat as high as 6.6-7.2 log cfu/g while Oumokhtar (2000) reported a mean TVC of 4.5 log cfu/g.

Since TVC is typically high in raw poultry, so is the risk of microbial spoilage (Javadi, 2011). Researchers have correlated spoilage with total bacterial counts on the surface of the carcass: a sour, "dish raggy" off-odor becomes evident when the population density on the carcass has reached approximately 10^7 cfu/g and formation of slime occurs when counts reach the 10^8 cfu/g threshold (Wabeck, 2002). The bacterial count on a product is believed to depend on three factors: time, initial bacterial load (Banwart, 1989) and the temperature history of the product at all stages of production and subsequent storage and handling (Pooni and Mead, 1984). Microbial flora on carcasses such as the Specific Spoilage Organisms (SSO) break down fats and proteins and cause other biochemical changes which result in undesirable flavours and odours (Wabeck, 2002).

There are various important sources of microbial contamination during the slaughtering and downstream processing. The birds being processed are thought to represent the major reservoir of microbes in a poultry processing plant. Plant workers, air, dust, water, supplies, equipment and materials are also important vehicles or vectors of microbial transmission (Wabeck, 2002).

Prevalence of *Escherichia coli* in raw chicken

A higher level of *E. coli* was found in chicken purchased from markets than supermarkets (Table 7). Mean population of 5.0 and 4.4 log cfu/g were observed for main markets M1 and M2 respectively while *E. coli* was undetectable by plating (< 2 log cfu/g) in chicken purchased from chilled outlets. Counts of *E. coli*, a member of the coliform group, noted in this study were comparable to that reported by Bhicoo (2011) who observed an average population of 5.6 log cfu/g of total coliforms for chicken sourced from markets. The author attributed the elevated counts to the long staging time at ambient temperature, the absence of refrigeration system and ineffective washing activities. On the other hand, Kozacinski et al. (2006) noted a lower average population of *Enterobacteriaceae* of 3.6 log cfu/g and 2.3 log cfu/g in fillets and chicken breasts with skin respectively. Similarly, Capita et al. (2002) noted lower counts of *Enterobacteriaceae* in samples of cut chicken meat (2.0 – 4.2 log cfu/g). This could be attributed to adoption of stricter hygienic practices and adherence to better time-temperature control. Cohen et al. (2007) reported that of all the samples analyzed in his study, 48% samples tested positive for *E. coli*. In our study, a prevalence rate of 50% can also be deduced with 20 out of 40 samples testing positive. Taken together, the high counts of TVC and *E. coli* of chicken purchased from markets reflect the poor sanitary conditions of slaughtering, handling and storage.

In addition to being used as an indicator organism of sanitary quality, *E. coli* is also used as an index organism of pathogens. *E. coli* originates primarily from the intestines of birds and, to a lesser degree, from workers or environment of the processing plant (Wabeck, 2002). Hence, maintaining low *E. coli* counts in poultry products is important to ensure hygienic food production as well as safeguard public health. Hence, it is recommended that growth of these organisms be controlled by minimizing contamination of slaughtered meat from intestinal contents, following good sanitary practices, and considering time-temperature control of product at retail.

Prevalence of *Staphylococcus aureus* in raw chicken

With regard to main chilled outlet CO1, the unacceptably high level of *Staphylococcus aureus* in samples obtained on the first visit provided grounds for rejection of the lot. However, the second batch was considered marginally acceptable as the level of *S. aureus* was detected in three out of five samples in the order of 10^4cfu/g.

Taken together, a mean bacterial cell density of *S. aureus* of 4.2-4.8 log cfu/g was observed for chicken purchased from markets and chilled outlets. Cohen et al. (2007) observed a mean population of *S. aureus* of 5.4 log cfu/g, which is 0.6-1.2 log cfu/g higher than in the current study. The high load observed in our study and that of Cohen et al. (2007) can partly be explained by poor personal hygiene of workers and traditional hand evisceration of poultry. Indeed, the presence and level of *S. aureus* in a food product closely reflects the level of personal hygiene of handlers and the degree of manual manipulation of food.

S. aureus was recognized as the second most common pathogen isolated from food samples at the Central Health Laboratory in Mauritius during the period of 1997-2007 (Hotee, 2011). In the current study, presumptive *S. aureus* was isolated in 65% of samples with a mean population of 4.2-4.4 log cfu/g. Cohen et al. (2007) observed a prevalence rate 10.4% with 20 of 192 poultry meat samples testing positive with an average population of 2.3-2.5 log cfu/g compared with 5.4 log cfu/g reported by Amara et al. (1994). Kozacinski et al. (2006) isolated *S. aureus* in 46% of samples of chicken breast fillets and in 29% of samples of breasts with skin with mean population of S. aureus of 2.7 and 3.0 log cfu/g respectively. Kreyenschmidt et al. (2002) evaluated the shelf-life of poultry meat and determined a density of *S. aureus* and staphylococcal species of 3.0 and 4.7 log cfu/g respectively. Abu Ruwaida et al. (1994) have also reported isolation of *S. aureus* in chicken meat at an approximate density of 4 log cfu/g.

S. aureus is the major *Staphylococcus* food poisoning species. Most *Staphylococcus* is introduced into the food-handling chain during preparation (Wabeck, 2002). Chicken meat becomes contaminated with *Staphylococcus*, usually through expulsion of these organisms into the air by infected humans through sneezing, coughing, breathing or talking (Wabeck, 2002). Although cells of *S. aureus* can be killed by subsequent cooking of the poultry product, the enterotoxins elaborated by the pathogen are heat-stable (BBB, 2012). If the product is held above 5°C for a long period of time, *Staphylococcus* will multiply rapidly. At levels of approximately 500,000 *S. aureus* cells per gram of raw meat product, enough toxins may be produced. Since the toxins are thermostable, they can withstand the cooking process thus causing food intoxication when the product is subsequently ingested

(Wabeck, 2002). Since a population density of *S. aureus* as high as 5 x 10^5 cfu/g was observed on several instances (Table 2 and 3), it clearly indicates that certain procedures need to be adopted to prevent contamination and multiplication of *Staphylococcus* such as ensuring cleanliness of poultry meat handlers, maintaining adequate sanitation of processing facilities and equipment and providing proper storage facilities.

Prevalence of *Salmonella* spp. in raw chicken

Salmonella was found in chicken from both main markets at a variable detection rate of 20-80%. A higher proportion of *Salmonella* positive samples (60-80%) were found at market M1 than market M2 (40-60%). On the other hand, chicken purchased from the chilled outlets harboured *Salmonella* at a frequency of ≤ 20% on both visits. The findings of this study are in agreement with those of Scheinberg et al. (2013) who also reported a higher prevalence of *Salmonella* in chicken sourced from farmers' market than supermarkets. Overall, 30% of samples tested positive for *Salmonella*. On the other hand, authors such as Kozacinski et al. (2002) and Zivkovicet al. (1997) reported a lower detection frequency of *Salmonella* (11%) in chicken meat samples and frozen ground meat respectively. Cohen et al. (2007) reported a significantly lower prevalence of *Salmonella* (1.6%) serotyped as *Salmonella enterica* serovar Hadar. Variations in the prevalence rates across studies can partly be explained by differences in poultry rearing densities, environmental temperatures, husbandry technologies and slaughtering processes of different countries. Taken together, the prevalence of 30% reported in our study is alarming and clearly showed that the health hazard in poultry products must not be underestimated.

The fact that *Salmonella* was also detected in samples from the supermarkets emphasizes that the animal itself represents the primary reservoir. *Salmonella* resides in the intestinal tracts of animals and is shed in the faeces; thus it is ubiquitous in nature forming a cycle that makes it prevalent throughout the environment (Wabeck, 2002). Principal sources of *Salmonella* organisms are dust, food handlers, pets, insects, rodents, birds, live-haul trucks and the air (Wabeck, 2002).

Our results highlight the need for a *Salmonella* reduction program starting with live production. Growing conditions should be kept as clean as possible, and feed ingredients containing animal or fish by-products should be laboratory-certified free of *Salmonella*. Hatcheries have been shown in the past to be a major contributor of *Salmonella* to the young chicks (Manning, 2006). Dust should be eliminated from the environment, and equipment kept clean in the chick processing area of the hatchery. Clean-up procedures should include a sanitation program aimed at eliminating *Salmonella*, and should include spot bacterial checks prior to start-up of each day. The findings also reiterate the importance of thorough cooking and prompt cooling of poultry products, and it should always be fully reheated to 74°C prior to consumption.

Prevalence of *Campylobacter* spp. in raw chicken

Campylobacter was isolated from samples purchased from main markets M1 and M2 at a frequency of 40-80%. On the contrary, lots from both main chilled outlets were free of *Campylobacter* on both instances. Hence, lots from both markets should be rejected according to the microbiological decision criteria shown in Table 1. The prevalence of *Campylobacter* spp. was also found to be higher in chicken from farmer's markets (90%) compared to supermarkets (Scheinberg et al., 2013). The primary reservoir of *Campylobacter* is the intestinal tract of poultry. Hence, *Campylobacter* can easily be transferred from raw chicken to cutting boards, utensils and hands (Redmond and Griffith, 2004). These findings thus reflect the malpractices of food handlers and also the poor level of personal hygiene of vendors. A high prevalence of *Campylobacter* in raw broiler products of ca. 80% has also been reported elsewhere (Wabeck, 2002).

Comparative assessment of the microbiological quality of chicken from markets and chilled outlets

TVC and *Escherichia coli* counts are often used as hygiene indicators to evaluate the microbiological profile of raw chicken (Scheinberg et al., 2013). However, *E. coli* is the parameter of choice to evaluate the effectiveness of sanitation practices and potential faecal contamination of meat (USDA-FSIS, 1996). In this study, TVC and *E. coli* counts were found to be significantly higher in markets than chilled outlets ($P<0.05$). Scheinberg et al. (2013) similarly found that TVC and *E. coli* were higher in raw poultry products from farmers' market compared to industrially processed chicken. The load of *S. aureus* in poultry on the other hand, reflects the level of hygiene of the handler (Cohen et al., 2007). Poultry bought from markets (4.6-4.8 log cfu/g) had a significantly higher density of *S. aureus* ($P<0.05$) than chilled outlets (3.0-4.2 log cfu/g). Since poultry sellers at the market have a greater propensity to manually handle the products, the findings therefore suggest a poor level of personal hygiene of handlers operating at the markets. At the outlets however, handlers have been observed to wear gloves and to change them after every two servings. Additionally, at chilled outlets, sellers were observed to use tongs in lieu of hands when serving customers.

CONCLUSION

The level of TVC, *E. coli* and *S. aureus* were persistently higher in poultry bought in markets compared to those purchased at the chilled outlets. *Salmonella* and *Campylobacter* were also detected at a higher frequency in chicken purchased from markets than those purchased from chilled outlets. The Ministry of Health and Quality of Life of Mauritius should provide more frequent educational training to food handlers especially those operating in markets, which will help to enhance their knowledge in food safety. Additionally, more rigorous inspections and routine

microbiological testing of poultry ought to be conducted by third parties.

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